# MODIS DATA SYSTEM STUDY

## TEAM PRESENTATION

**December 9, 1988**

## AGENDA

1. Outstanding Issues and Uncertainties
2. On-Board Processing
3. Data Acquisition and Processing Strategy

## OUTSTANDING ISSUES AND UNCERTAINTIES

With an expected launch of the first NASA Polar Orbiting Platform (NPOP-1) in late 1996, we have some eight years to wait before the first data taken in flight by the MODIS-N and MODIS-T instruments is received and processed. Before this milestone is achieved, the MODIS data system must be fully designed, built, and tested. At this stage, however, the Phase-B design studies for the instruments are not yet completed, the members of the MODIS science team have not yet been selected, and the structure and concept of the EosDIS is still evolving. It is not surprising that there exist some uncertainties, at this time, in specific areas of the MIDACS operations concept. The uncertainties fall into two categories: those driven through a lack of specific definition of the EosDIS environment, and those driven due to a lack of specific knowledge concerning the MODIS instruments'capabilities and the science team members' proposed research objectives.

### Real-time Monitoring of Data

Engineering and science data taken by the MODIS instruments, as well as selected platform ancillary data, must be monitored in the ICC. Ideally, all data of possible utility would be available in real time with a 100% duty cycle. However, the primary downlink will be through the TDRSS, and it is anticipated that the platform will have access to the TDRSS for only portions of each orbit. Each TDRSS access generally scheduled well in advance of the actual contact. While there will be an alternate, multiple-access low-rate data path for the transmission and verification of emergency commands, the TDRSS link will be the sole path for downlinked data destined for the monitoring function within the ICC. Engineering and science data taken between TDRSS contacts will be stored on board the platform for playback and downlink at the time of the next TDRSS contact.

Under these circumstances, it will not be possible to monitor the instrument with a 100% duty cycle in real time. With priority-playback processing at the DHC, the data may be monitored with a 100% duty cycle either in real-time or shortly after reception by the DIF. It is anticipated that the platform and instrument ancillary data (engineering/housekeeping) will be packetized seperately from the science data, and that these packets will be automatically routed to the ICC.

There is a requirement that science team or IOT members located in the ICC monitor four channels each of MODIS-N and MODIS-T data in real time, and that the choice of the channels being monitored be selectable in real time. There are three possible methods for achieving this:

1. The data are buffered on board the platform by the instrument data system during each scan. Data from different channels are packetized separately. All MODIS data is treated as either real-time or priority-playback

data by the DHC. A split pipe flow may exist, with Level-0 processing functions performed twice for some MODIS data, allowing the MODIS ICC to receive the data quickly, and the CDHF to receive the data after the gaps in coverage have been filled. Within the ICC, the headers of the Level-0 data packets are examined, and data from selected channels only are ingested into the monitoring data base; non-selected data are lost.

2. As in the previous example, the science data is buffered and reorganized prior to the generation of data packets. However, in this scenario, the ICC uplinks to the on-board data system in real-time the selected subset of channels to be monitored. The on-board data system installs the real-time/priority-processing designation and ICC address in the header of the packets of data required for monitoring. Upon acquisition at the DHC, the designated packets of data are delivered immediately to the ICC, perhaps with only partial Level-0 processing. Within the ICC, the data are received at a relatively low rate, unpacked, and inserted into the monitoring data-base. Data from unselected channels are not available with this timeliness, but may be analyzed at a later time (24+ hours after observation) upon completion of processing at the CDHF.

3. In this case, we assume that the on-board processor does not buffer the MODIS data during a scan (on the order of ten megabytes for MODIS-T). Each packet of science data then contains data from many spectral channels multiplexed together. All MODIS data is treated as either real-time or priority-playback data by the DHC. As with the first example, there is no interactive, real-time selection of channels to be monitored between the ICC and the on-board processing system. Because of the absense of on-board data sorting by channel, the science data required for monitoring at the ICC must be collated from observations contained on many packets. All MODIS data packets are required, and many aspects of the Level-0 and -1A processing are required to unpack and reorganize the data into a form useful for monitoring. The size of processor required will exceed that normally associated with typical control and monitor functions and may reside on the CDHF.

Implementation of Algorithms for Standard Product Processing

Capabilities of the On-Board Processor

Non-MODIS Instrument Data Availability

Non-MODIS instrument data availability from other EOS and non-EOS sources.

## Near-Real-Time Data Communication

Communication of near-real-time data from the CDHF/DADS to field experiments.

## Data Processing Operations Concept

The level of meaningful detail in the processing operations concept is limited by our knowledge of the processing algorithms. Details of the processing scenarios and concepts such as the logical data record, Earth location, and calibration accuracy will evolve with our understanding of processing algorithms and end-user requirements.

## Capabilities and Interfaces of the MIDACS with the DHC

What are the current capabilities of the DHC to support the real-time, near-real-time, and routine science data processing time-lines that are required by the MIDACS? The DHC will process some data for real-time delivery to the MIDACS (ICC or CDHF) for monitoring. The DHC will also pass the priority playback data to the MIDACS, but it is still uncertain how this will be accomplished. This DHC/MIDACS interface has not been fully clarified.

## On-Board Processing

Impact of the ICC workload for planning and scheduling/control and monitoring functions if the ICC has the added responsibility to uplink commands for the selection of channels to be monitored. The ICC personnel would have to work more directly with the EMOC/PSC/NCC for the scheduling of TDRSS contacts to accomplish this. Also, the increase of work due to many requests for data or the rapid selection of channels would pressure ICC personnel to make quick decisions without the ability to follow defined procedures and guidelines for the checking and verification of all command loads.

## Storage of the MODIS Science, Engineering, and Ancillary Data

These data will be stored either at the ICC, EMOC, or MIDACS DADS. This has an impact on the required storage capacity of ICC or wherever the data are stored.

## Implementation of DARs for Real-Time Field Experiments or Instrument Calibration

The current schedule will be interrupted for each request. The number of such requests is unknown at this time. Any request for real-time support would effect the TDRSS scheduling and, therefore, needs to be coordinated with the appropriate facility to satisfy the reqest.

## Hierarchy of Requests

The hierarchy of priority for the request for field experiments or real-time monitoring and the availability of workstations at the ICC to provide support.

Command Tracking of TOOs and Real-Time Requests

The ICC must verify the command load for all commands uplinked to the MODIS before they are transmitted to the EMOC. The procedure and timeline for doing this must be defined.

MODIS/HIRIS and Joint Scheduling with Other Instruments

The MODIS and HIRIS will have some sort of interaction, not only for the planning and scheduling phase, but also for the impacts of requests for data in the real-time and near-real-time for the support of field experiments for MODIS and coincident observations for HIRIS. A prioritized scheduling process must be developed.

MIDACS Support Personnel

The role of the product support analysts and the system operators with respect to the production of standard data products.

## ON-BOARD PROCESSING

The MODIS-N and -T instruments will contain processing capabilities which are yet to be fully defined. In addition to controlling the physical operation of the instrument, the analog-to-digital conversion of the measurements, and data packet generation, the processor will be responsible for many other functions. The on-board processor is not a part of the ground data system supporting the MODIS data reduction and, due to the presence of the TDRSS, DIF, and DHC, no physical interface exists between the two data systems. However, there is a clear functional interface between the on-board and ground data systems, both of which comprise the MODIS data system. The reason for considering the on-board processing in this specifications document is simple: the two systems must function as a single entity, and data must flow transparently between the two. There are functions which must be performed by either the on-board or ground data systems (such as data buffering and sorting), and functions which must be reversed on the ground if performed in flight (such as data compression).

### On-Board Data Buffering and Formatting

The on-board data system could buffer complete scans of data, and sort the measurements by channel prior to packetization.

### On-Board Data Selection

The on-board data system could allow the on-board selection of data to reduce return data link requirements during periods of resource conflicts and provide a graceful system degradation in the face of restrictions on the return data link capability (e.g., spectral channel selection, intermittent usage of "sharpening" bands).

### On-Board Data Compression

The on-board data system could support the performance of either a lossless or lossy data compression.

### On-Board Data Processing

On-board processing of data could generate some products which could be used to control the instrument (e.g. set detector gains for land/sea, alter sensing routine based on cloud cover, etc.)

### On-Board Packet Addressing

On-board addressing (e.g., MODIS CDHF or ICC) and priority designation (e.g., real-time or priority playback) of packets to support real-time monitoring and near-real-time support of field experiments.

### On-Board Data Packet Building

The on-board data system could build data packets for subsampled real-time monitoring of science data, as well as on-board data packet building for ancillary and engineering/housekeeping data, and other special purpose packets of interest to the ground data system (e.g., from the platform LAN, generate platform ancillary packets, or packets summarizing the duty cycles and selected observations from other instruments on the platform).

Command and Scenario Storage and Execution

Command and scenario (e.g., sunglint avoidance, automatic gain changes for high solar zenith angles, internal calibration sequences) storage and execution

Improve Instrument Reliability

Provide or support built-in instrument self-test capability, provide fault detection and automatic instrument safing, or support command alternatives to correct instrument failures (e.g., built-in instrument redundancy).

DATA ACQUISITION AND PROCESSING STRATEGY

Here we consider the generation of standard MODIS data products within the CDHF as a part of EosDIS. The MODIS CDHF is responsible for:

1. Simultaneously generating MODIS standard products at Levels -1A, -1B, -2, -3, and -4.

2. Supporting field experiments and the observation of targets of opportunity through the generation of near-real-time products.

3. Reprocessing standard products at a rate of at least twice the real-time rate.

4. Supporting (in some not yet fully determined manner) algorithm developmental activities in their final stages prior to integration, perhaps in the form of special processing requests.

The CDHF will, as a part of its processing of 1, 2, and 3 above, routinely generate the corresponding browse data and metadata. The requirements constraining these activities (and others, such as routine maintenance) will be met jointly and, in doing so, it is not expected that the resources in the CDHF will be utilized beyond a level of 50% to 70%.

Requirements for MODIS Standard Product Generation

The strategy for the routine generation of standard Level-1 through Level-4 data products within the MIDACS, and specifically the CDHF, is driven by a number of functional and performance requirements. The sources of these requirements and related constraints include the MODIS/HIRIS Level-I Requirements Document, the MIDACS Functional Requirements Document, and other EosDIS and scientific documentation. Most important are the following:

1. MIDACS shall force no delays in the processing operation which preclude the direct flow of acquired data through the system.

2. The routine delivery of Level-0 data to MIDACS will not be guaranteed any sooner than 24 hours after the observation. (Priority playback or real-time data will be available sooner to support higher priority processing such as field experiment support.)

3. The combined sampling rate for the MODIS-N and MODIS-T instruments will be on the order of 10**6 radiance measurements per second and 10**11 measurements per day.

4. All MODIS observations will be processed to yield standard data products to Levels -1A, -1B, -2, and -3 by MIDACS.

5. MIDACS will process and make available data through Level-1B within 48 hours of observation; through Level-2 within 72 hours of observation; and through Level-3 within 96 hours of observation.

6. On the order of 100 standard level-2 products will be generated by MIDACS.

7. Browse data and metadata associated with the standard products will be delivered to archive with the same timeliness as the products themselves.

8. MODIS sensor data will be sequentially ordered by buffering and processing, either on board the platform or in the Level-1A processing, by scan line and then channel.

Requirements Analysis for MODIS Standard Product Generation

Taken literally, the first requirement clearly states that the processing software must be capable of processing MODIS observations as they are received, i.e., on an observation-by-observation basis. Conventionally, however, it is common to accumulate some amount of data before processing is begun (perhaps up to one orbit of data, or one day of data for a lower-rate instrument). If the MODIS sensor data is spectrally/ chronologically reordered as a part of the Level-1A processing, then the smallest convenient parcel of data for processing is one complete scan. For MODIS-N, with eight 1-km resolution detectors along track, this is just over one second of data. For MODIS-T, with 64 1-km resolution detectors along track, this corresponds to about 10 seconds of data. Though not anticipated, if spatial resampling along the scan were to be performed as a part of the Level-1B processing, then the smallest convenient parcel of data for processing is a complete scan line from one detector, or about 1/6 second of data. For most Level-2 applications, multiple collocated spectral bands of radiances will be required to generate geophysical parameters. In some conceivable Level-2 applications, collocated observations from the same spectral channel but from different points along the orbit (with varying zenith/azimuth angles) will be needed. At Level-3, multiple orbits of data will be needed to perform spatial averaging and mosaicking.

It seems reasonable to process the MODIS data in segments, thus forcing some delay in the processing of the earliest observations of the time period covered by the segment. The exact length of the processing segment must await the results of a trade-off study considering both I/O and RAM storage factors, but will be in the range of from one scan to one orbit of data (and may be a variable). In either case, the processing system can track the data segment through a unique label (scan number and orbit number). On the order of 10**4 and 10**3 segments of MODIS-N and MODIS-T data, respectively, would be acquired daily. Once a segment of data is processed from Level-0 to Level-1A, it can then be processed to Level-1B, and then to Level-2, without waiting for additional segments to be processed. Incidentally, this procedure may facilitate the processing of subsets of the MODIS data in near-real-time without the need for duplication of effort.

Let us assume that the MODIS instrument data is organized into physical records corresponding to complete scans of data. [When stored on magnetic tape, physical records are separated by inter-record gaps and are thus easily located; on optical storage, a physical record might simply be associated with the absolute address of the start of the record.]

Within each record, the sensor data is sorted by channel, and by detector scan line within each spectral channel of data (Tables 1 and 2). For the case of MODIS-T, this will create a physical record approximately ten megabytes in length. The first three logical records will contain the identification, ancillary, and georeference data. The remaining 64 logical records will each contain the radiance for a single spectral channel. This structure facilitates the spectral subsetting of the Level-1B product within the DADS to meet specific data requests.

Level-2 standard products can be organized in precisely the same manner, simply by substituting geophysical products for the calibrated radiances. However, there are many arguments for not all Level-2 parameters on the same physical record or data set. In particular: (1) the terrestrial, oceanic, and atmospheric data will ultimately reside in different long-term archives; (2) there will rarely be a simultaneous need for more than a subset of Level-2 parameters; and (3) reprocessing at Level-2 will generally occur individually for each product, and not globally as might be the case for Level-1B. This opens the question as to whether it will be necessary to produce and archive repetitive information for each product. It may be sufficient to have a standard Level-2 georeference product, which is accessed by the DADS in the process of filling orders at the same time as the requested products.

So as to optimize the throughput in the CDHF and DADS, processors should be designed to process physical record n, while simultaneously writing data associated with physical record n-1 and reading physical record n+1. In this manner, the processing will not be I/O bound and the highest throughput will be achieved. While processing data from the physical record, the calculations will be repetitive, thus providing the opportunity for vector or parallel processing.

It is clear that the data rates and volumes, coupled with the short delivery periods required for the certified standard products, require that any CDHF data processing strategy be developed well in advance of the application. Only by specifying this methodology early, to the level of the product, physical record, logical record, and algorithm, will the processing throughput be optimized and the most cost-effective data system created.

## Level-1 Standard Product Generation

There will be two Level-1 MODIS standard products: Level-1A and Level-1B. The 1A product will, by definition, be reversible to Level-0. As such, no science or ancillary information will have been lost in its generation. The primary uses of 1A data will be: (1) to expedite the processing of higher-level MODIS data and (2) as an archive resource to permit possible future reprocessing of MODIS data. The 1A data will also be used by the CST for the maintenance of the MODIS calibrations. The Level-1B product will be derived solely from the Level-1A data and will no longer be reversible to Level-0. Most of the instrument and platform ancillary data will not be required at higher levels of processing, and thus probably will not be retained at Level-1B (although the ancillary data volume will be small compared to that of the sensor data). The ancillary data that is retained will be irreversibly transformed: platform attitude and ephemeris and instrument pointing information into observation vectors and footprint locations; observation vectors and solar ephemeris into satellite and solar zenith angles and relative azimuth. Some or all of the instrument data will be irreversibly transformed through the application of nonlinear calibrations. Once used, the detector voltages and instrument temperatures will have no higher-level application.

The production of a Level-1A data record will require the assemblage of many packets of Level-0 data. These packets will have been delivered by the DHC and will be:

1. Error corrected to a bit error rate of $10^{-10}$ to $10^{-12}$. (At $10^{-12}$, on average only one bad MODIS bit will be encountered every day. However, at a bit error rate of only $10^{-8}$, 10,000 bad bits will be encountered daily.) The packets with uncorrectable errors will be flagged as such by the DHC. The MODIS Science Team will require a bit error rate of no worse than $10_{-10}$.

2. Arranged in chronological order, with duplicate packets deleted, and without any gaps in coverage to no less than the 99.9% level. (Because MODIS data will be used to produce products with global coverage, missing packets will degrade the quality of the final product. Completeness to only the 99% level would result in a loss of 15

minutes of coverage; at 6.5 km per second, this is a 51° or 5600 km swath along the orbit.) The MODIS Science Team will require coverage to no less than 99.9%.

3. Composed of the set of all MODIS science and ancillary data packets, and all platform and other ancillary data packets required for processing.

The Level-1A records will be created by collecting information from the various input data packets, unpacking the data from the packets, and organizing them into the physical records. Other information, not derived directly from the Level-0 data, will be required. This data will include calibration coefficients and algorithm/processing history information.

The production of a Level-1B data record will require only the Level-1A data as input. As such, it may be computationally efficient to produce the 1B data record immediately upon completion of the 1A record, and while the 1A data is still in memory. (Note that this strategy would preclude intervention by the CST for purposes of altering the calibration in near-real-time. As conceived, the 1B data will actually be composed of three types of information: identification data, ancillary data, georeference data, and radiance data. (Because the georeference data, and probably each of the first three data types, will be useful to users of the Level-2 data products as well, it may be useful to put the information into a common data base shared by the Level-1B and -2 products within the MIDACS and later in long-term archive. As such, the MODIS standard product would actually be "distributed," with cross-referenced elements residing in two separate locations. In the process of filling a Level-1B or -2 order by a MODIS data user, the DADS would generate a file structure similar to that in Tables 1-2 by combining information from the Level-1B, -2, or georeference data sources.)

Level-2 Standard Product Generation

The production of a Level-2 data record will require the corresponding Level-1B data, and other instrument data, as input. While the Level-1A and 1B products contain all the MODIS instrument data at that processing level, at Level-2 there will exist many standard products. Each product may contain one or more related parameters. The different Level-2 products will be produced from the same Level-1B data. These Level-2 products will apply:

1. Globally, as with estimates of cloudiness and radiation budget components.

2. To specific surface types, as with sea surface temperature or phytoplankton over the oceans only, vegetative index and soil moisture over land only.

3. Regionally, such as snow/ice bidirectional models over the polar regions, precipitation and irrotational flow estimates over the tropics, and specific interests for only certain areas of the Earth.

From I/O considerations, it may be computationally efficient to generate all Level-2 products "at the same time." Here we do not mean processing the different parameters simultaneously, but instead creating physical records for all Level-2 products from the same 1B record before processing the next 1B record. As noted in the previous section, the Level-2 products might share common georeference information. It is anticipated that this mode of processing will be possible for many or most of the Level-2 algorithms. However, certain Level-2 products will require additional information:

1. Collocated looks by MODIS-T at the same region from two or more different tilts (from within the same orbit).

2. Collocated views by both MODIS-N and MODIS-T at the same region.

3. Simultaneous data from other instruments on board the same polar platform.

4. Collocated data from instruments on board other platforms or systems, including conventional (ground, balloon, ship, or aircraft) data.

In some or all of these possible situations, the generation of the specific Level-2 product would have to occur independently, perhaps after processing of all Level-1B and the simpler Level-2 products was completed for the day of data. As additional standard Level-2 products are approved for generation, production of the parameters will commence on the day the algorithms are integrated. The processing of data computed from these new algorithms for the period prior to integration will be treated as with reprocessing: handled separately from the routine data stream and at least twice the real-time data rate.

## Level-3 Standard Product Generation

## Level-4 Standard Product Generation

## Scheduling of MODIS Standard Product Generation

The production of MODIS products is, by definition, hierarchical: lower-level products are required as input into algorithms designed to generate higher-level products. There can be no Level-1 product without Level-0 data, and no Level-2 products without Level-1B data. However, the product levels need not always be produced in sequence: Level-3 products may be generated from either Level-1B or Level-2 data, and Level-4 products may be generated from either Level-2 or Level-3 data (or perhaps both). Many Level-2 products will be produced from subsets of the same Level-1B data, sometimes in concert with information from non-MODIS data sources.

Processing the MODIS data in segments (such as complete instrument scans) permits the data to be handled in terms of records. Some 1,000 to 10,000 of these segments of data will have to be processed through all data levels on a daily basis for MODIS-N and MODIS-T. There will be up to 100 Level-2 products generated by MIDACS. Each product will consist of one or more parameters and will have either global or regional coverage. As a result, on the order of $10^6$ separate processing steps will be required to get through Level-2. This processing will occur on a daily basis, 7 days a week, 52 weeks a year. A high degree of automation will expedite the operation of this facility. It is possible that an expert system will be required to optimally control the data processing operation. The software would need to consider each of the guidelines and constraints a human operator would use: availability of the input information, memory/IO/CPU efficiency, memory/online storage management, timeliness requirements, conflicting demands for resources for reprocessing and other applications, scheduled maintenance, etc.

After standard data products are created, yet before they are placed into archive, additional processing is required:

1. The data must be certified. As anticipated, algorithms will be supplied to the CDHF by the MODIS Science Team along with certification criteria. Data passing these quality assurance criteria will be considered certified and will be delivered to the DADS for archival. Data failing these quality assurance tests will either: (a) not be delivered to the DADS or (b) delivered to the DADS as noncertified data and flagged for limited (Science Team only) distribution. In either case, the Science Team will be notified that the certification criteria are not being met.

2. The browse data must be created. Browse data will be single-byte spectral and spatial summaries/subsets of the full resolution MODIS products. Two types of browse data have been defined: (a) 20 kilometer resolution, single-byte latitude/longitude scenes, with four spectral channels each for MODIS-N and -T as well as for each of their Level-2 parameters, eight of these scenes cover the Earth, and an additional eight of which are defined for specific domains of general interest (e.g., Antarctica, tropical Pacific Ocean); (b) four kilometer resolution single-byte cross-track/along-track scenes, with two

spectral channels each for MODIS-N and -T, twenty of these scenes cover each orbit (ten during daylight only for MODIS-T). This data will require storage equivalent to less than 0.5% of the full resolution MODIS data.

3. The catalog information must be compiled. This data will contain information regarding the complete histories of the product and its parent data sets, including the algorithms used, DQA statistics, and any other relevant information.

4. The metadata must be generated. The metadata is a summary of the characteristics of the data product, which may be broken down in terms of each processing segment. Metadata will be specifically directed towards assisting the MODIS data user in selecting and manipulating MODIS data.

This additional data must be produced within the CDHF prior to delivery at the DADS. It is possible that the DQA, browse, and metadata can be produced on a record-by-record basis, while the catalog information (equivalent to header and trailer records on a MODIS product file or volume) must await the completion of processing for the product (e.g., one day of data in the case of Levels 1-2).

TABLE 1. LEVEL-1B MODIS-T PRODUCT PHYSICAL RECORD STRUCTURE:

Instrument ID
    1 Byte

Orbit Number/Scan Number
    5 Bytes

Data History (Input Data History/Algorithm Version/Calibration Version/Processing Date)
    4,000 Bytes

Instrument Ancillary Data (e.g., Instrument Tilt/Operating Mode)
    2,000 Bytes

Platform Ancillary Data (e.g., Observation Time)
    2,000 Bytes

Data Quality Information
    64 Channels * 64 Scan Lines / 8 Bits = 512 Bytes

Anchor Point Earth Locations/Earth-Sun-Satellite Geometry
    20 Bytes * 64 Scan Lines * 1,294 Pixels / 4 Pixels per Anchor Point / 4 Scan Lines per Anchor Point = 103,520 Bytes

Calibrated Radiances
    64 Channels * 64 Scan Lines * 1,294 Pixels * 2 Bytes = 10,600,448 Bytes

--------------

| | |
|---|---|
| Identification Logical Record: | 4,006 Bytes |
| Ancillary Data Logical Record: | 4,512 Bytes |
| Georeference Logical Record: | 103,520 Bytes |
| Channel 1 Radiance Logical Record: | 165,632 Bytes |
| Channel 2 Radiance Logical Record: | 165,632 Bytes |
| Channel64 Radiance Logical Record: | 165,632 Bytes |
| Total Physical Record Length | 10,712,486 Bytes |

Number of Physical Records per Orbit: 313 (Day Only)
Number of Orbits per Day: 14

TABLE 2. LEVEL-1B MODIS-N PRODUCT PHYSICAL RECORD STRUCTURE:

Instrument ID
    1 Byte

Orbit Number/Scan Number
    5 Bytes

Data History (Input Data History/Algorithm Version/Calibration Version/Processing Date)
    4,000 Bytes

Instrument Ancillary Data (Mode of Operation)
    2,000 Bytes

Platform Ancillary Data (e.g., Observation Time)
    2,000 Bytes

Data Quality Information
    94 Detectors per Kilometer * 8 Kilometers / 8 Bits = 94 Bytes

Anchor Point Earth Locations/Earth-Sun-Satellite Geometry
    20 Bytes * 8 Scan Lines * 1,294 Pixels / 4 Pixels per Anchor Point / 4 Scan Lines per Anchor Point = 12,940 Bytes

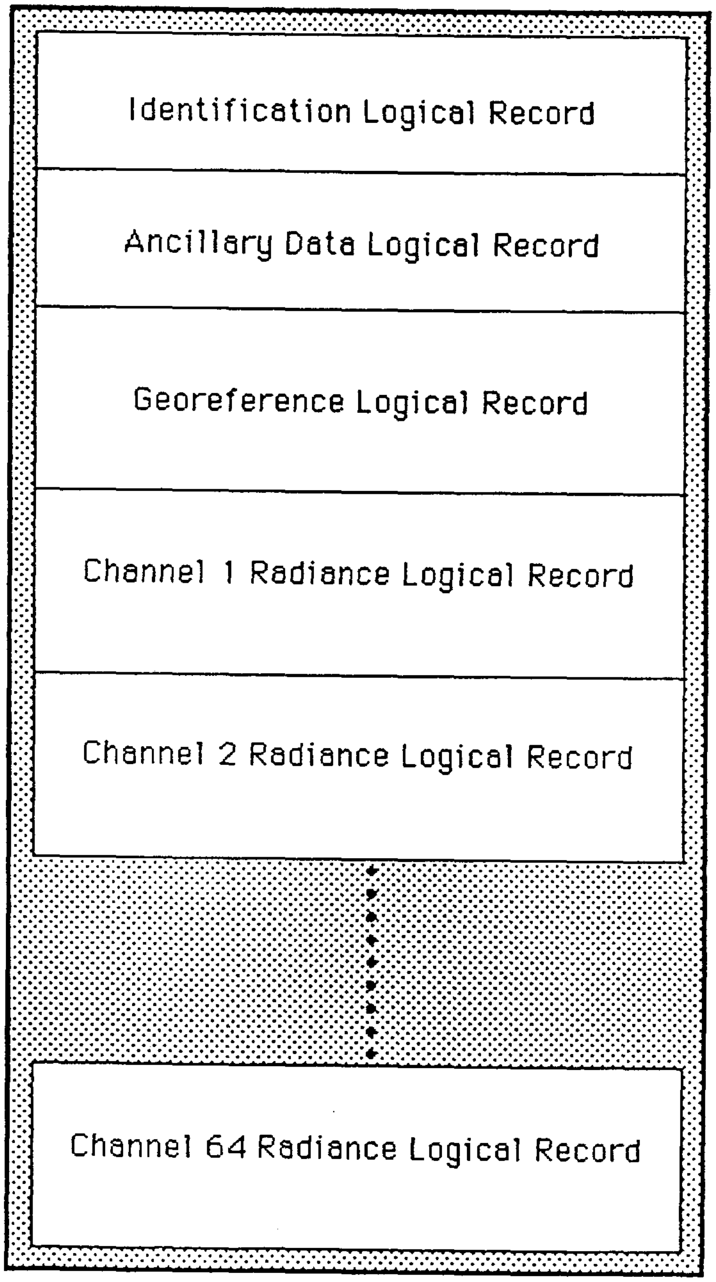
Calibrated Radiances
    94 Detectors* 8 Scan Lines * 1,294 Pixels * 2 Bytes = 1,946,176 Bytes

--------------

| | |
|---|---|
| Identification Logical Record: | 4,006 Bytes |
| Ancillary Data Logical Record: | 4,512 Bytes |
| Georeference Logical Record: | 12,940 Bytes |
| Radiance Logical Record (1 km res): | 20,704 Bytes |
| 30 channels during day | |
| 15 channels during night | |
| Radiance Logical Record (500 m res): | 20,704 Bytes |
| 8 channels during day | |
| 0 channels during night | |
| Radiance Logical Record (250 m res): | 20,704 Bytes |
| 2 channels during day | |
| 0 channels during night | |
| Total Physical Record Length | 10,607,656 Bytes |

Number of Physical Records per Orbit: 626
    313 (Day Only)
    313 (Night Only)
Number of Orbits per Day: 14

# MODIS-T Level-1B Product Physical Record Structure



# MODIS-T Level-1B Product File Structure